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U.S. Department of Agriculture

THE PRESENT STATUS OF FOOD DEHYDRATION IN THE UNITED STATES*

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While drying is the oldest form of food preservation, it has been replaced to a great extent by canning and freezing as a world wide method. At the present time, however, owing to war conditions, it has again taken its place as an important industry. There are several well defined reasons for this: where transportation is a problem, dried food has decided advantages both as to weight and bulk over canned or frozen food; with little or no tin available for use on food containers, dried food has another advantage in that it can be packed in containers composed of materials that are practically unrestricted as to use.

During the First World War considerable dehydrated food was sent abroad. Much of it was poor in quality; consequently the efforts made to establish this food as a part of the civilian diet met with little response. In addition to poor quality, the dried product had to be reconstituted slowly and was at a decided disadvantage in the home in competition with a canned product which required only opening of the can and heating.

When the present emergency was first anticipated, dehydration investigations were again initiated. An order was issued by the Chief of the Bureau of Agricultural Chemistry and Engineering creating an Executive and Operating Committee on Dehydration and instructing that committee to formulate and prosecute a program of research for the purpose of improving dehydrators and dehydrated food products. Active work under this program was started early in the summer of 1941. It has consisted of engineering studies of the existing types of driers and of ways and means for their improvement; surveys to determine the more concentrated areas of vegetable production; studies of the effects of processing on the chemical constituents and the physical character of the fruits and vegetables; and studies of storage and packaging problems.

It soon developed that a large part of the Committee's time would be taken up in answering correspondence and meeting persons interested in dehydration problems. Many visitors merely had personal schemes which they wanted the Government to finance; but some were seriously considering the general problems incident to large-scale production.

When the work began, most of the vegetable and fruit dehydration was being carried out on the Pacific Coast. A large number of fruit driers for prunes and raisins, and also some for apples and hops, had been operating in their respective fields for years. Although most of these drying plants were in locations where truck crops were abundant, not all of them could be economically adjusted to dry vegetables. Some half dozen, however, have been so altered and are now operating, one plant having handled a hundred tons of cabbage every 24 hours for several months. In addition, there were four vegetable dehydrators capable of handling a considerable daily tonnage. Two of these were drying miscellaneous vegetables to be used largely in soup mixtures; the other two were drying onions and garlic almost exclusively.

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Operations on this type in 1941 produced between 6,000,000 and 7,000,000 lbs. of dehydrated products.

When it became apparent that there would be a demand for dried vegetables far in excess of the capacity to produce with the present set-up, a large number of enterprising people wanted to change over their existing facilities or erect new driers. Fortunately, there were several factors tending to hold this enthusiasm in check, or there would have been more installations than the present force of trained operators could handle. A certain amount of restricted metals is necessary in any dehydrator, and each plant also has to have adequate vegetable preparation machinery before it can start. The latter requirement is usually difficult to meet, which is one reason why canners already having preparation equipment are in a better position to enter the dehydration field than many others.

It may not be out of place to briefly list the conditions and practices required for operation of a drying plant, and to present some of the problems involved.

Naturally, the first necessary precaution is to locate in a district where there is an abundance of vegetables. Our survey tables and maps will help in solving this problem, but it must be remembered that not all varieties of vegetables are suitable and that the same varieties grown in different regions do not always give the same quality of finished product. Usually quick growing succulent vegetables are not the best for drying. One advantage in locating in a truck crop area, in addition to the more obivious ones, is that short hauls and quick handling are important factors in ascorbic acid or vitamin C retention. Leafy vegetables, especially, lose their ascorbic acid very quickly after harvesting. Therefore, the dried product, if properly handled, has a distinct advantage over the fresh product which has been harvested for several days before it reaches the housewife. Where care is taken in dehydration, the product will carry more vitamins to the consumer than the average fresh product procured in the food markets. The advantages of rapid harvesting and hauling to the drier can, of course, be lost by slow or improper preparation and drying.

Thorough washing is essential and, as soon as the vegetables are pared or cut, they should be blanched. (One exception should be noted - onions are rarely blanched.) If any delay occurs at this point in the operation, the material should be held in cold water, or better, in a 1 or 2 per cent salt solution.

There are several types of blanching, steam or hot water being most commonly used. Some authorities suggest a series blanching in hot water (that is, the water is kept hot and used for successive lots of materials.) They recommend that the concentration of vegetable extractives in the water be kept at 1 to 5° Brix, depending upon the kind of vegetable, by adding fresh water continuously or from time to time. The Dehydration Committee favors steam blanching, owing to the higher vitamin retention and to the fact that the quality of water for blanching may vary in different parts of the country. Alkaline water and that containing excessive amounts of some salts will injuriously affect the final product. Blanchers may be either batch or continuous in type. Where cabinet driers are used, the blanching can be done in the cabinet just before the drying starts. A common error in blanching is to overload the trays or belt, resulting in underblanching a part of the material. If the blanching is not done on the trays, the blanched material has to be transferred to them and again the precaution must be taken not to overload.

After blanching, the drying process begins. Vitamin losses here vary with the

methods and the data obtained up to this time are not conclusive. However Table 3 shows the vitamin content of some freshly dried vegetables produced in a counter-flow air-blast tunnel.

Tunnel type driers can be parallel, counter, center-exhaust or cross flow. In parallel flow, the air current moves in the same direction as the material. The hot air enters at the wet end and is removed at the dry end so that the fresh material is in contact with the hottest and driest air; this is ideal. The dry end, however, is in contact not only with the cooler air current but also with a more or less saturated current, which is not ideal

Table 1 - Losses in Ascorbic Acid Resulting from Steam and Water Blanching.(Slide 1)

Commodity	Ascorbic Acid (Moisture-free basis) mg./100 gms.		Loss %
	Raw	Blanched	
Kale - Steam Blanched	909	730	19.7
" - Water Blanched	753	425	43.6
Beets - Steam Blanched	52.2	44.5	14.8
" - Water Blanched	45.4	28.8	36.6
Potatoes, White - Steam Blanched	35.5	27.5	22.5
" " - Water Blanched	34.7	21.7	37.5
Cabbage - Steam Blanched	385	331	14.1
" - Water Blanched	398	193	51.5

Table 2 - Loss of Ascorbic Acid in White Potatoes: Steam Blanched, Water Blanched, and Water-Series Blanched. (Slide 2)

Treatment	Ascorbic Acid mgs./100 gms.	Loss %
Raw	7.7	-
Steam Blanch - 4 minutes	7.0	9.1
" " - 8 minutes	6.6	14.3
Water Blanch - 10 parts water, 1 part potatoes	5.2	32.5
Water Blanch - 20 parts water, 1 part potatoes	3.1	59.8
Series Blanching:		
After first use of water	5.1	33.8
" third " " "	5.5	28.6
" sixth " " "	4.9	36.4
" tenth " " "	4.9	36.4

Table 3 - Vitamin Contents of Freshly Dried Vegetables (calculated on dry basis)

(Slide 3)

Commodity	Treatment	Ascorbic Acid mg./100 gms.	Thiamin mg./100 gms.	Riboflavin mg./100 gms.	Carotene mg./100 gms.
Cabbage	None	369	0.57	0.89	-
Cabbage	Blanched	354	0.63	0.83	-
Spinach	None	155	-	-	46
Carrots	Blanched	-	0.39	0.38	140
Sweet Potatoes	10 min. cook	26	0.15	0.37	19
White Potatoes	20 min. cook	14	0.44	0.26	-

In counter-flow driers, these conditions are reverse. The hottest and driest air enters at the dry end, while the wet end is in contact with the cooler and partly saturated air.

Both of these types are being superseded by the center-exhaust type, where two streams of air are used, each moving from end toward the center of the dehydrator. In this way each half is somewhat independent of the other. Usually a partition of canvas or other material separates the two ends and is removed only when the trucks are moved forward. This type affords opportunity to regulate temperature and humidity in each half and comes nearer to giving ideal conditions in each end.

In cross flow types, the air blows across the trays and is recirculated to other trays, that is, each truckload of trays in effect becomes a cabinet but with unimpeded movement of the trucks. Cabinet driers are single compartments or a series of compartments. They afford opportunity to regulate temperature and humidity during the drying with an ease not obtained in other types.

Drying times differ with heat, air flow, tray loading, etc. The recommendation of the Committee has been to use as high a velocity as can be attained economically, and as high a temperature as is possible without scorching or otherwise injuring the flavor of the product. We find better vitamin C retention in hot rapid drying than in slower, cooler operation.

Some dehydrators follow the plan of removing their products while still too

wet to store (15 to 20 per cent moisture) and reducing the final moisture to about 5 per cent by drying in bulk overnight. The bins in which this operation is carried out are so arranged as to have a slow draft of air moving through them at a temperature around 110-120° F. A few hours in them will reduce the moisture satisfactorily. After drying, the vegetables are removed from the bins and packaged when cool.

The Committee recognized the fact that packaging is one of the important phases of the dehydrated food problem. Manifestly it is of no avail to produce material of excellent quality and then package it in such a way as to limit its storage life to a few weeks. Much time, thought and labor have been spent on this part of the work and a large volume of data has been accumulated, too large, in fact, to attempt to treat it thoroughly in this paper. Only the high lights will be given here, but very shortly it is hoped that a further presentation can be made in a separate paper.

A consideration of vitamin losses during the preparation, drying and storage of dehydrated vegetables is of importance. In the first place, treatment of the vegetable between the time of harvest and delivery to the dehydrator determines the vitamin content of the raw product. Losses of vitamin C are greatest during this period. They are especially high with leafy material which, on standing over night in lug boxes, will lose one third of their vitamin C content. If cut, the loss will be greater, and if stored at relatively high temperatures, the rate of loss will be higher. There is some loss even when stored at 40° F. We have records from poor storage and delays showing a loss of over two-thirds of the vitamin C in spinach in 24 hours.

Carotene, the precursor of Vitamin A, is more stable but is affected by light. The carotene of carrots is highest near the outer layer and toward the lower end, so that light damage may be considerable.

Thiamin (vitamin B_1) and riboflavin are fairly stable on short storage of the raw material.

In order to keep this paper within reasonable limits, tables showing the field losses are not given. Freshly harvested vegetables vary greatly in their vitamin contents. We have a record of a variation in spinach from adjacent fields of from 3 to 100 milligrams per 100 grams, determinations being made within 2 hours of the harvesting. Therefore too much dependence must not be placed on published data as to vitamin C content.

After drying, storage becomes a very important factor. Time does not permit a lengthy discussion of this phase of the problem. It can be shown, however, that losses in vitamins, palatability and color occur on storage. Storage samples used here were placed in sealed #2 sanitary cans. Where inert gas was used, the cans were evacuated in a vacuum can closing machine, and the vacuum was broken twice with the gas to be used. This was not altogether successful; up to 5 per cent of oxygen was found in the cans on testing at the end of the experiments. However, this compares favorably with the amount of oxygen found in commercial packs in nitrogen or carbon dioxide. We have now improved the method so as to leave less than one percent oxygen in the package. But data on the results are not yet available.

Palatability of the samples was scored by a selected jury, the members of which were able to identify replications with accuracy. The samples were reconstituted and cooked. Aroma and texture tests were made while the jurors were blindfolded.

The blindfold was removed and the sample again tested. The average of all scores was recorded. A grade of 1 was excellent, 2 good, 3 fair, 4 without odor or flavor but with no distasteful quality, and 5 distasteful or disagreeable odor or flavor.

Where specifications require packing in inert gas, the flushing of air out of the container must be carefully and thoroughly carried out. Merely thrusting the gas tube to the bottom of the can, leaving it for a few seconds and then withdrawing it will leave from 5 to 7 per cent of oxygen in the container. It must be remembered that both nitrogen and carbon dioxide as sold contain from 3/10 to 1/2 per cent of oxygen. With care in keeping the lid as far as possible over the opening of the can and moving the tube, through which the gas is flowing, about in the can, we have been able to keep the content of oxygen below 2 per cent. Tests for oxygen in the sealed can should not be made until 24 hours after the can is sealed.

Color records given in the tables are based on the Munsell color scheme as determined by Dr. Charles E. Sando alone, so that the personal equation involved is constant. Records are on the reconstituted samples.

Storage was at 90° F., the samples being taken at 4, 8 and 16 week periods when it was possible to do so. In addition to air, carbon dioxide, nitrogen and oxygen were used on identical samples; oxygen was used to see if the deleterious effects of oxydation might be hastened and thus afford a means of estimating what might take place on prolonged storage. The effect of the moisture content of the samples on their keeping quality is also shown.

(Tables 4 to 7 incl.)

Starting with blanched carrots having a moisture content of 7.2 per cent, we find that after 8 weeks storage in air the palatability had changed from good to fair, the hue had changed from 2.1 Yellow-Red to 3, and the chroma and brilliance had not materially changed. Carotene content had dropped from 140 milligrams per 100 grams to 77 mgs./100 gms., and thiamin and riboflavin had not changed within the limit of analytical error.

The samples containing 9.8 and 13.5 per cent moisture showed progressive deterioration in palatability. As the moisture was increased a stage was reached where little aroma or flavor was apparent. Color deterioration was not great, however, and there was no greater loss of carotene than in the sample of 7.2% moisture content.

In samples stored in nitrogen, even with 5 per cent oxygen left in the cans, there was less deterioration than was shown by air storage. The low moisture sample changed from good to fair in palatability, and the medium moisture sample after 16 weeks' storage had not changed further. The high moisture sample was somewhat less palatable after 16 weeks. There was little, if any, change in any of the color tests. Carotene had held better than where the carrots were stored in air, dropping from 140 mgs./100 gms. to 110-113 mg./100 gms.

Stored in carbon dioxide, the low moisture content sample showed little change in color or palatability after 8 or 16 weeks. Carotene losses, however, were greater than where stored in nitrogen; there was a drop from 140 mgs./100 gms.---------

In oxygen, as was to be expected, deterioration was more marked. All samples became flavorless; there was marked color degradation; and the carotene was

Table 4 - Dehydrated Carrots Stored in Air

Storage, weeks	Moisture %	Munsell Color (Reconstituted Samples) Hue	Chroma	Brilliance	Palatability*	Carotene	Thiamin	Riboflavin
						milligrams/100 grams		
0	7.2	2.1Yr	5.4	12.6	2.0	140.0	0.39	0.37
4	7.2	2.5YR	5.5	12.4	3.2	109.0	0.28	0.53
8	7.2	3 YR	5.4	12.2	3.1	82.0	0.35	0.65
16	7.2				3.0	77.0	0.44	0.59
0	9.8	2.1YR	5.4	12.6	2.0	140.0	0.39	0.37
4	9.8				3.5	114.0		
8	9.8	3.6YR	5.3	12.2	3.5	93.1		
10					3.8	79.8		
0	13.5	2.1YR	5.4	12.6	2.0	140.0	0.39	0.37
4	13.5				3.2	102.0		
8	13.5	3.8YR	5.3	11.8	3.0	77.6		
16	13.5				4.4	79.1		

Table 5 - Dehydrated Carrots Stored in Nitrogen

0	6.4	2.1YR	5.4	12.6	2.0	140.0	0.39	0.37
4	6.4				2.0			
8	6.4	2.3YR	5.4	12.9	3.4	133.5		
16	6.4				3.0	110.0	0.31	0.49
0	8.9	2.1YR	5.4	12.6	2.0	140.0	0.39	0.37
4	8.9							
8	8.9				3.0	111.9		
16	8.9	2.5YR	5.3	12.2	3.0	112.0		
0	12.5	2.1YR	5.4	12.6	2.0	140.00	0.39	0.37
4	12.5							
8	12.5	2.3YR	5.1	11.8	3.4	113.1		
16	12.5				3.5	113.0		

* Palatability: 1=excellent; 2=good; 3=fair; 4=without odor or flavor but with no distasteful quality; 5=distasteful or disagreeable odor or flavor. "Good" was the highest rating given by the juries on any product, either fresh or dehydrated and possibly should be rated higher.

Table 6 - Dehydrated Carrots in Carbon Dioxide

Storage, weeks	Moisture %	Munsell Color (Reconstituted Samples) Hue	Chroma	Brilliance	Palatability*	Carotene	Thiamin	Riboflavin
						milligroms/100grams		
0	6.8	2.1YR	5.4	12.6	2.0	140.0	0.39	0.37
8	6.8	2.3YR	5.3	12.2	2.7	86.6		
16	6.8				2.4	90.3	0.31	0.49
0	7.6	2.1YR	5.4	12.6	2.0	140.0	0.39	0.37
8	7.6	2.5YR	5.2	12.0	2.7	100.1		
16	7.6				2.8	88.6		
0	11.4	2.1YR	5.4	12.6	2.0	140.0	0.39	0.37
8	11.4	2.6YR	5.2	12.0	3.0	100.8		
16	11.4				2.8	90.7		

Table 7 - Dehydrated Carrots Stored In Oxygen

0	6.5	2.1YR	5.4	12.6	2.0	140.0	0.39	0.37
2	6.5	3.7YR	5.5	11.7	3.0	75.2		
4	6.5	4.2YR	5.6	11.8	4.0	69.3		
8	6.5	5.3YR	5.5	10.8	4.0	36.5		
16	6.5					27.2		
0	9.2	2.1YR	5.4	12.6	2.0	140.0	0.39	0.37
2	9.2							
4	9.2				3.8			
8	9.2	5.8YR	5.6	10.9	4.0			
0	11.6	2.1YR	5.4	12.6	2.0	140.0	0.39	0.37
2	11.6							
4	11.6				3.8			
8	11.6	7.2YR	5.7	10.0	4.0			

* Palatability; 1=excellent; 2=good; 3=fair; 4=without odor or flavor but with no distasteful quality; 5=distasteful or disagreeable odor or flavor.

practically eliminated, dropping to 11.6 mgs./100 gms.

The results indicate that when packed in either nitrogen or carbon dioxide, dehydrated carrots retained their flavor to a fair degree. Packed in nitrogen, the carotene retention was about 80 per cent; in carbon dioxide, it was about 65 per cent.

(Tables 8 to 11 incl.)

Samples of blanched cabbage having a low moisture content (3.7 per cent), which were stored in air, showed a little color change in 8 weeks, and only slight flavor changes and a reduction of ascorbic acid from 354 mgs./100 gms. to 230 mgs./100 gms. (65 per cent retention) in 16 weeks. There was no loss of thiamin or riboflavin.

Moisture content plays a greater role here than in the case of carrots, for the 8 per cent moisture samples showed definite loss of color and palatability, and a very serious loss of ascorbic acid (only one 11 per cent retention). The third set of samples, having a moisture content of 10.2 per cent, showed somewhat more deterioration as to color and palatability, and a heavier loss of ascorbic acid. All data are on 16 weeks' storage.

Where nitrogen was used, there was no color deterioration, although poor sampling resulted in some uneven data. All samples lost in palatability, becoming tasteless. Again, the samples with the higher moisture contents showed increased losses of ascorbic acid. After 16 weeks' storage, the 3.8 per cent sample retained 80 per cent of the vitamin C; the 6.7 per cent sample retained 56 per cent; and the 8.4 per cent sample retained only 25 per cent.

The data on the low moisture samples held in carbon dioxide are as yet incomplete. In the others, there were some color changes, the palatability was only fair, and the ascorbic acid losses were large.

There was very little difference between the samples stored in oxygen and the samples stored in air, except that in oxygen the low moisture content samples lost more ascorbic acid than those in air. In the higher moisture content samples, there was little difference between air and oxygen storage.

(Tables 12 to 15 inc.)

Sweet potatoes stored in air retained their color well at the end of 8 weeks, where the sample contained but 5 per cent moisture. At 9 per cent moisture, there was no change in a month, and where the moisture was raised to 12 per cent, the sample molded.

In the low moisture samples stored in air, palatability remained unchanged after 8 weeks, and the carotene had dropped from 19.3 mg./100 gms. to 15.4 mg./100 gms., a retention of 80 per cent. There was no change in the ascorbic acid.

At 9 per cent moisture content, the carotene retention was 70 per cent, but the ascorbic acid fell from 25.5 to 9.5 mgs./100 gms., about one-third retention. There was some riboflavin loss in all the samples, and the thiamin results are inconclusive. It must be remembered that the present methods for determining such small amounts of thiamin and riboflavin are not accurate within 20 per cent and perhaps more. Frequent duplicates were run, and in some cases checks were made by

Table 8 - Dehydrated Blanched Cabbage Stored in Air

Storage, weeks	Moisture %	Munsell Color (Reconstituted Samples) Hue	Chroma	Brilliance	Palatability*	Ascorbic Acid milligrams/100 grams	Thiamin	Riboflavin
0	3.6	9.5Y	5.8	3.6	2.6	354.0	0.63	0.83
4	3.6	9.4Y	6.1	3.4	3.9	278.0	0.53	0.83
8	3.6	9.5Y	6.2	3.4	3.1	264.0	0.54	0.83
16	3.6					230.0	0.54	0.78
0	8.2	9.5Y	5.8	3.6	2.6	354.0	0.63	0.83
4	8.2	7.8Y	5.9	3.4	3.8	179.0	0.64	0.92
8	8.2	7.3Y	6.0	3.3	4.0	92.3	0.50	0.92
16	8.2					35.8	0.48	0.78
0	10.2	9.5Y	5.8	3.6	2.6	354.0	0.63	0.83
4	10.2	4.0Y	5.8	3.4	4.7	126.0	0.63	0.89
8	10.2	6.0Y	5.8	3.3	4.1	45.6	0.59	1.11
16	10.2					21.1	0.46	0.76

Table 9 - Dehydrated Blanched Cabbage Stored in Nitrogen

0	3.8	9.5Y	5.8	3.6	2.6	354.0	0.63	0.83
4	3.8	9.5Y	6.1	3.5	2.0			
8	3.8	9.4Y	6.4	3.6	4.0	299.0	0.57	0.88
16	3.8					285.0	0.61	0.30
0	6.7	9.5Y	5.8	3.6	2.6	354.0	0.63	0.83
4	6.7							
8	6.7	9.0Y	6.1	3.4	4.0	254.0	0.65	0.91
16	6.7					199.0	0.60	0.27
0	8.4	9.5Y	5.8	3.6	2.6	354.0	0.63	0.83
4	8.4							
8	8.4	6.5Y	6.2	3.2	4.0	159.0	0.61	1.04
16	8.4					91.6	0.61	0.27

*Palatability: 1=excellent; 2= good; 3= fair; 4=without flavor but with no distasteful quality; 5=distaste 1 or disagreeable odor or flavor.

Table 10 - Dehydrated Blanched Cabbage Stored in Carbon Dioxide

Storage, weeks	Moisture %	Munsell Color (Reconstituted Samples) Hue	Chroma	Brilliance	Palatability*	Ascorbic Acid milligrams/100 grams	Thiamin	Riboflavin
0	4.3	9.5Y	5.8	3.6	2.6	354.0	0.63	0.83
4	4.3							
8								
16								
0	6.7	9.5Y	5.8	3.6	2.6	354.0	0.63	0.83
4	6.7							
8	6.7	7.8Y	5.7	3.7	4.0	213.0	0.59	0.96
16	6.7				4.0	152.0	0.50	0.70
0	11.9	9.5Y	5.8	3.6	2.6	354.0	0.63	0.83
4	11.9							
8	11.9	5.5Y	5.7	3.1	3.5	76.2	0.37	0.79
16	11.9				inedible	42.0	0.40	0.89

Table 11 - Dehydrated Blanched Cabbage Stored in Oxygen

0	3.7	9.5Y	5.8	3.6	2.6	354.0	0.63	0.83
2	3.7	9.4Y	5.9	3.2	3.5	867.0		
4	3.7	9.6Y	6.0	3.2	4.0	229.0	0.52	0.88
8	3.7	9.2Y	5.9	3.2	3.3	199.0	0.54	0.88
16	3.7				4.0	162.0	0.54	0.75
0	7.8	9.5Y	5.8	3.6	2.6	354.0	0.63	0.83
2	7.8				3.0	193.0		
4	7.8				3.9	107.0		
8	7.8	7.4Y	5.8	3.2	4.0	53.3		
16	7.8				inedible	76.0		
0	10.00	9.5Y	5.8	3.6	2.6	354.0	0.63	0.83
2	10.00				3.6	127.0		
4	10.00				4.0	52.0		
8	10.00	6.8Y	5.9	3.1	4.1	19.4		

*Palatability: 1=excellent; 2=good; 3=fair; 4=without odor or flavor with no distasteful quality; 5=distasteful or disagreeable odor or flavor.

Table 12 - Dehydrated Sweet Potatoes Stored in Air

Storage, weeks	Moisture %	Munsell Color (Reconstituted Samples) Hue	Chroma	Brilliance	Palatability*	Carotene	Thiamin	Riboflavin	Ascorbic Acid
						Milligrams per 100 grams			
0	5.0	7.8YR	6.4	9.4	2.3	19.3	0.15	0.37	25.5
2	5.0				2.5				
4	5.0	7.4YR	6.0	9.9	2.6	14.8	0.13	0.37	
8	5.0	7.5YR	5.9	8.7	2.4	12.7	0.24	0.58	41.5
16	5.0					15.4	0.22	0.12	27.0
0	9.0	7.8YR	6.4	9.4	2.3	19.3	0.15	0.37	25.5
4	9.0	7.8YR	6.1	9.5	3.0	13.1	0.13	0.38	
8	9.0				2.8	16.1	0.23	0.55	32.0
16	9.0					13.5	0.20	0.12	9.5
0	12.0	7.8YR	6.4	9.4	2.3	19.3	0.15	0.37	25.5
4	12.0		molded		molded	17.9	0.12	0.45	
8	12.0					17.1	0.21	0.51	11.7
16	12.0					10.9	0.18	0.19	6.0

Table 13 - Dehydrated Sweet Potatoes Stored in Nitrogen

0	5.5	7.8YR	6.4	9.4	2.3	19.3	0.15	0.37	25.5
4	5.5	7.8YR	6.3	8.7	3.5				
8	5.5	7.1YR	6.1	10.0	3.5	16.4			
16	5.5					15.9			
0	9.2	7.8YR	6.4	9.4	2.3	19.3	0.15	0.37	25.5
4	9.2								
8	9.2	7.7YR	6.0	9.6	3.4	13.3			
16	9.2					14.1			
0	14.4	7.8YR	6.4	9.4	2.3	19.3	0.15	0.37	25.5
4	14.4								
8	14.4	8.2YR	6.1	9.0	3.3	17.4			
16	14.4					15.3			

*Palatability: 1=excellent; 2=good; 3=fair; 4=without odor or flavor but with no distasteful quality; 5=distasteful or disagreeable odor or flavor.

Table 14 - Dehydrated Sweet Potatoes Stored in Carbon Dioxide

Storage, weeks	Moisture %	Munsell Color (Reconstituted Samples) Hue	Chroma	Brilliance	Palatability*	Carotene	Thiamin	Riboflavin	Ascorbic Acid
						milligrams per 100 grams			
0	6.1	7.8YR	6.4	9.4	2.3	19.3	0.15	0.37	25.5
4	6.1	7.5YR	6.1	9.5	4.0		0.15	0.48	31.0
8	6.1	8.2YR	6.0	8.9	2.5	17.4	0.20	0.45	39.0
16	6.1								
0	9.5	7.8YR	6.4	9.4	2.3	19.3	0.15	0.37	25.5
4	9.5						0.13	0.50	30.0
8	9.5	8.3YR	5.9	8.5	3.3	19.3	0.14	0.44	27.0
16	9.5								
0	12.2	7.8YR	6.4	9.4	2.3	19.3	0.15	0.37	25.5
4	12.2						0.16	0.50	15.0
8	12.2	8.0YR	6.0	8.8	3.0	15.0	0.14	0.41	14.2
16	12.2								

Table 15 - Dehydrated Sweet Potatoes Stored in Oxygen

0	5.7	7.8YR	6.4	9.4	2.3	19.3	0.15	0.37	25.5
2	5.7				3.1	14.1			
4	5.7	8.2YR	6.2	9.4	3.0	18.5			
8	5.7	8.6YR	6.0	9.3	4.0	36.1			
16	5.7					8.6			
0	10.4	7.8YR	6.4	9.4	2.3	19.3	0.15	0.37	25.5
2	10.4								
4	10.4	7.8YR	6.2	9.4	2.7				
8	10.4				3.3				
0	13.6	7.8YR	6.4	9.4	2.3	19.3	0.15	0.37	25.5
2	13.6								
4	13.6		Molded		Molded				
8	13.6								

*Palatability: 1=excellent; 2=good; 3=fair; 4=without odor or flavor but with no distasteful quality; 5= distasteful or disagreeable odor or flavor.

independent laboratories.

In nitrogen, none of the samples showed marked color changes. There was a definite loss of palatability but increased moisture content did not increase this change. Carotene retention was about 80 per cent in all samples, regardless of moisture content. Ascorbic acid was not run on this set.

In carbon dioxide, the color retention was about the same as in nitrogen; palatability was unchanged in the low moisture content samples, but was lowered in the other samples from good to fair. Carotene retention was about the same as in the samples stored in nitrogen. Ascorbic acid remained the same in the two lots, but some of the results were out of line. In the high moisture content samples (12 per cent), there was a 56 per cent retention of carotene. Thiamin and riboflavin did not change.

In oxygen, the color changes were not marked, but the palatability was lowered; in the low moisture sample there was a loss of over half the carotene in 16 weeks.

Summarizing very briefly, carrots should be dried down to 5 per cent moisture, or lower, and packed in either carbon dioxide or nitrogen. The eating quality of those stored in carbon dioxide is better, but carotene retention is better in nitrogen.

With cabbage, there is little choice between storage in nitrogen, carbon dioxide and air, except that ascorbic acid retention is greater in the nitrogen-stored samples.

Dehydrated sweet potatoes keep well if dried down to 5 per cent moisture, but show less effect from higher moisture than do carrots or cabbage. Palatability is fair when stored up to eight weeks and carotene retention is good.

The final table (Table 16) is in response to many inquiries we have received. It shows the amount of dehydrated vegetables necessary to produce 1 pound of the rehydrated product. Rehydration was determined by soaking until the product had taken up all the water it could absorb. This usually amounted to about 80 per cent of the original content. The results vary somewhat but the figures are a fair average.

Table 16 - Amount of Dehydrated Vegetables (containing about 5% moisture) required to produce one pound of rehydrated product.

Commodity	Amount required to produce 1 lb. rehydrated product
Beets	2.4 ounces
Cabbage	1.5 "
Carrots	3.3 "
Chard	2.9 "
Kale	2.8 "
Mustard Greens	2.8 "
Onions	2.3 "
Sweet Potatoes	6.2 "
White Potatoes	2.7 "
Spinach	2.3 "
Turnips	5.0 "